DOPPLER EFFECT AND COMPENSATION IN A ROTATING FANBEAM SPACEBORNE SCATTEROMETER

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1. INTRODUCTION

The Rotating Fanbeam Scatterometer, RFSCAT, will be the next generation satellite radar-instrument to provide wind speed and direction near the sea surface. Spaceborne RFSCAT has a wider continuous swath that can provide a large number of independent samples of Sigma0. But the large swath and footprint result in wideband Doppler frequency shift. In this paper, the simulation of Doppler Effect and compensation methods in a RFSCAT are presented. The maxim Doppler bandwidth between forward and backward echoes will be 500 KHz. Even in a single echo of RFSCAT, the Doppler bandwidth is about 90 KHz, while in a pencil beam scatterometer the Doppler frequency is almost a single tone [1]. So in a RFSCAT, it is hard to compensate the full band Doppler frequency entirely as a pencil beam Scatterometer does. If only compensate the center frequency of Doppler shift, the residual Doppler frequency will also degrade the accuracy of Sigma0 seriously. A method of compensating both center frequency and chirp rate of the echoes are carried out and evaluated. The compensation system design and implementation are discussed at the end of this paper.

2. SYSTEM PARAMETERS IN SIMULATION

The main system parameters in the simulation are listed in Table 1. The emitted complex signal can be written as:

$$S(t) = a_0 \cdot \exp\left[j2\pi (f_c t + \frac{\alpha}{2} t^2) \right] \quad (1)$$

The received signal $S_r(t)$ is the convolution of the emitted signal S(t) with the reflectivity of the ground a:

$$S_r(t) = a \cdot s(t-\tau) \cdot \exp\left[j2\pi f_D(\tau)(t-\tau) \right] + n(t) \quad (2)$$

Where n(t) models the noise, f_D is the Doppler frequency, a is the ground reflectivity function [2] [3].

3. DOPPLER EFFECT IN A RFSCAT

Figure 1 shows the time joint frequency distribution of a forward echo. Receiving time window and antenna pattern cause a sharp amplitude change. The transmitted Linear Frequency Modulation (LFM) Pulse becomes

Table 1 System Parameters in the Simulation

Orbit	514km
Frequency	13.256GHz
Polarization	HH and VV
Ground Resolution	<50km
Emission Power	120W
Antenna	3dB Beam width: 20º; Gain=30
PRF	150Hz
Platform Velocity	7050m/s
Earth Radius	6378km
Transmitted Chirp	B=500KHz; T=1.3ms
Antenna Pattern	30dB @ 32°~ 48°
Footprint	~ 400km
Receiving Time Window	4ms~6.8ms(after emission)

nonlinear because of Doppler effect. More than 500 KHz Doppler bandwidth need to be compensated for whole view geometry and 90 KHz Doppler bandwidth for a single echo (at forward or backward view). The Doppler frequency shift is confused both in time domain and frequency domain, so it is hard to compensate entirely. Figure 2 compares the spectrums of forward and backward echoes. The spectrums indicate that not only the center frequency but also the bandwidth and return power are different between the forward and backward echoes. The reason is that the Doppler effect broaden or compress the spectrums of the echoes while the whole energy scattering from the sea surface is a constant for the same sea state. Thus the range gate distribution and the Sigma0 estimation of the echoes need to be reassigned due to different azimuth angle. [4]

4. DOPPLER COMPENSATION METHOD

A method of using the time-frequency character of standard receiving echoes instead of the transmit signal as dechirp reference is applied here to compensate the Doppler frequency shift. The main characters of the compensation system are shown as below [5]:

- Shift center frequency of transmit chirp to make sure the echoes are centered at the pass band of receiver.
- Adjust the FM ratio of dechirp signal to compensate the Nonlinear Doppler frequency shift.
- Establish a lookup table of Doppler compensation based on different azimuth angle and orbit.
- All compensations are accomplished by DDS easily.

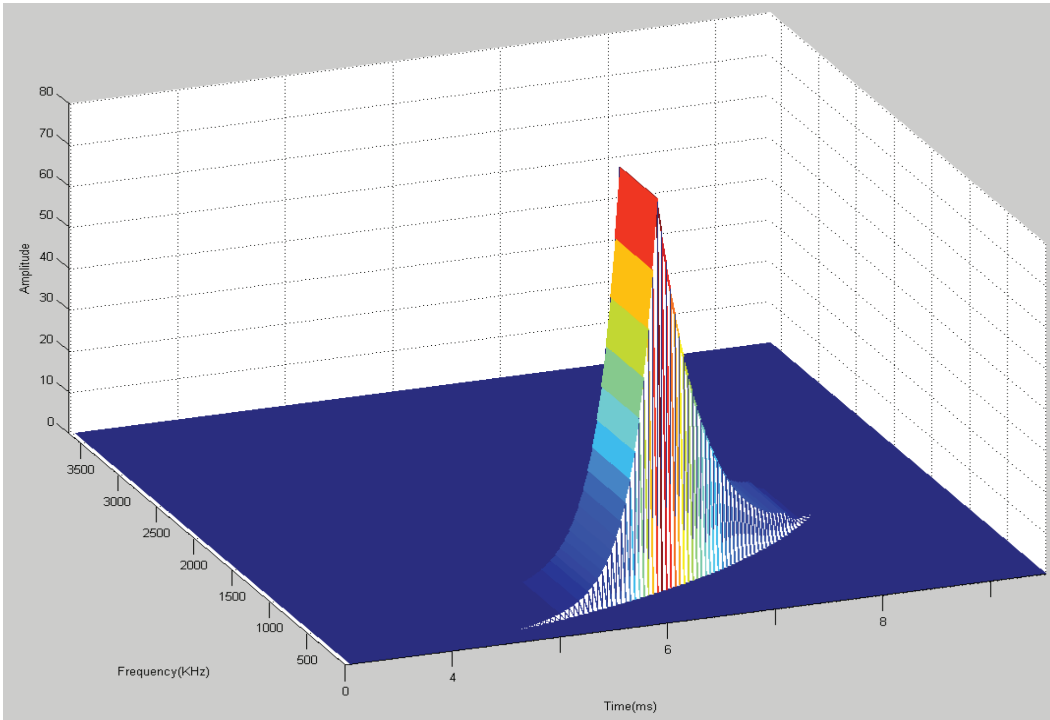

Fig.1 Time and Frequency distribution of forward echo

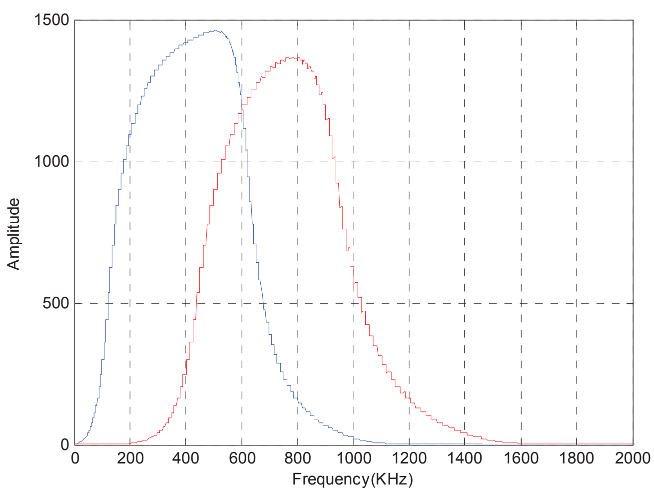

Fig.2 Spectrum of forward and backward echoes

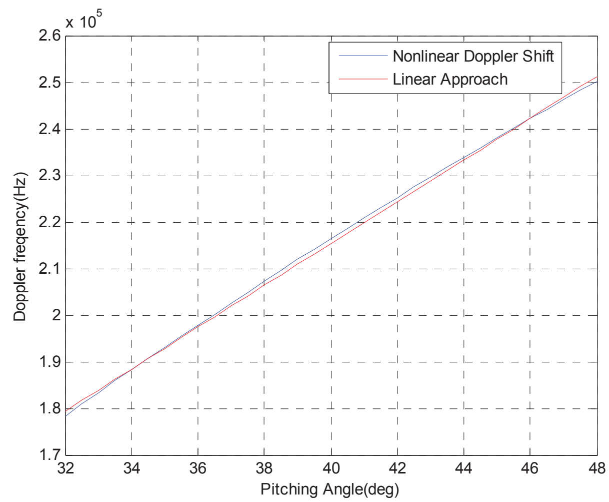

Fig.3 Linear Approach to Nonlinear Doppler shift

Figure 3 shows the linear approach to the nonlinear Doppler shift of received echoes. As a result, when using linear approach signals as dechirp reference, only 1 KHz Doppler frequency are left uncompensated, about 300m range mismatch. While 90 KHz Doppler bandwidth will cause about 30km range error. Figure 4 shows the block diagram of Doppler compensation. The chirp ratio compensation can also be pre-compensated in TX DDS to simplify the hardware structures.

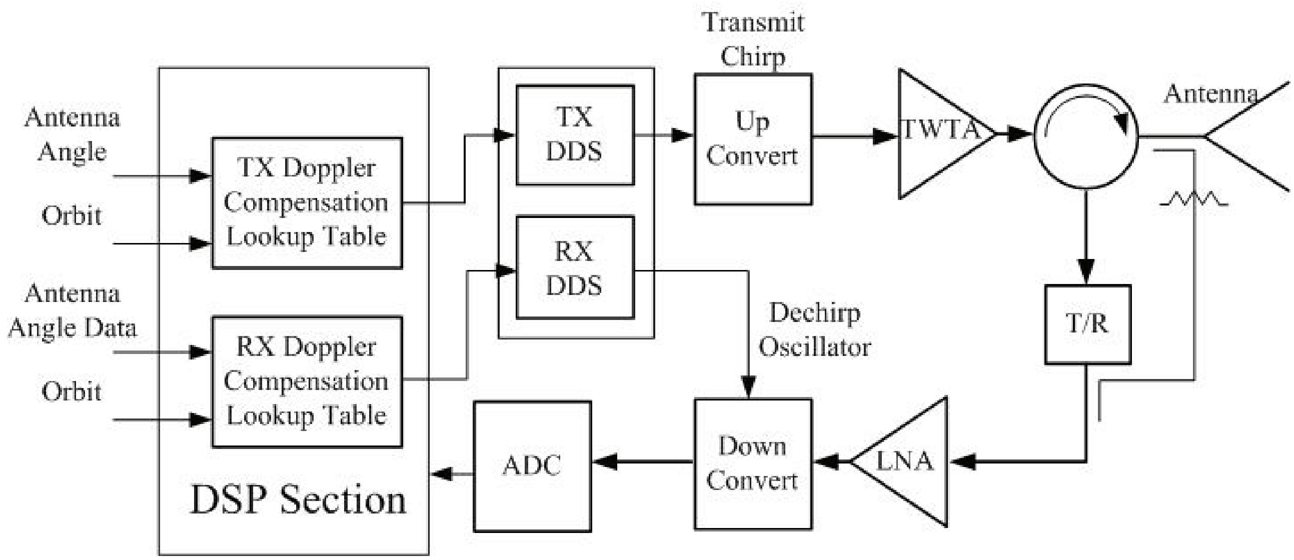

Fig.4 Block Diagram of Doppler Compensation

11. REFERENCES

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